Journal of Forestry Research (2010) 21(3): 311–318
DOI: 10.1007/s11676-010-0076-1

ORIGINAL PAPER

Shifting cultivation effects on soil fungi and bacterial population in Chittagong Hill Tracts, Bangladesh

Sohag Miah • Soma Dey • S. M. Sirajul Haque

Received: 2009-11-19 Accepted: 2010-01-02

Abstract: A study was conducted at two pair sites of Chittagong Hill Tracts in Bangladesh to find out the effects of shifting cultivation on soil fungi and bacterial population. The first pair of sites with shifting cultivation and village common forest-managed by indigenous community was at Madhya Para in Rangamati district and the second pair of sites with the shifting cultivated land and village common forest at Ampu Para in Bandarban district of Chittagong Hill Tracts. At both the locations with two different land uses, soil textures in surface (0–10 cm) and subsurface (10–20 cm) soils varied from sandy loam to sandy clay loam. Soil pH and moisture content were lower in shifting cultivated land compared to village common forest. The results also showed that both fungal and bacterial population in surface and subsurface soils was significantly ($p \leq 0.05$) lower, in most cases, in shifting cultivated land compared to village common forest at both Madhya Para and Ampu Para. At Rangamati and Bandarban in shifting cultivated lands, *Colletrotrichum* and *Fusarium* fungi were absent and all the bacterial genus viz. *Coccus, Bacillus* and *Streptococcus* common in two different locations with different land uses. Common identified fungi at both the land uses and locations were *Aspergillus*, *Rhizopus*, *Trichoderma* and *Penicillium*. Further study can be done on the other soil biota to understand the extent of environmental deterioration due to shifting cultivation.

Keywords: shifting cultivation; fungi; bacteria; soil biological properties; village common forest; Chittagong Hill Tracts; Bangladesh

Introduction

Rapid population increase in mountainous watershed of Chittagong Hill Tracts (CHTs) of Bangladesh is the main clue for intense environmental stress including soil. One of the reasons for the increasing population in CHTs is the rapid settlement and expansion of people from over populated plain area in shortage of agricultural land. The other reason is the construction of an earth dam in 1955 across the Karnaphuli River at Kaptai in CHTs to generate hydropower. The high increase rate of population both from native and migrated people was also the cause of increasing population in CHTs. In this hill tract on 13 180-km^2 land, thus population increased to 1.5 million altogether in 2009 (Wikipedia 2009) from 61 957 indigenous and 1097 non-indigenous people in 1872 (Suhrawardy 1995). Settlement of people from plain land to CHTs brought many different changes in traditional culture of indigenous people. This also created pressure on forests and all other natural resources in CHTs. Forests and lands owned and used earlier by local communities only, have now been used by the settlers also. Thus, same amount of resource due to share of more people had been created scarcity. Therefore, this has become a serious livelihood issue and created chronic poverty and community conflict on land to people of CHTs. About 75-km^2 reserved and 600-km^2 un-classed state forest areas as well as about 220-km^2 cultivable lands were submerged from construction of dam on Karnafuly River at Kaptai in 1955 for generation of hydroelectricity. In effect, about 100 000 peoples from 18 000 families became homeless, shifted to further uphill areas and started to clear the forest for habitations and subsistent agriculture (Newman 1974). Newly constructed road to remotest areas of this hilly region also accelerated deforestation rate rapidly through settlement and abusive agriculture. Over time natural forest of the area has been reduced at a faster rate through deforestation and shifting cultivation. In the process of deforestation, forest was removed illegally due to collection of fuel wood, timber for business, over cutting of forests and overall mismanagement of the forest. At present, vegetation cover of definite type is not permanent over an extensive area as well as in compact form, because of rotational shifting cultivation. Shifting cultivation based on slash-and-burn method for land preparation and locally known as 'jhum', is a common agricultural land use in CHTs. In the past,

Foundation project: This study was supported by United States Department of Agriculture (USDA), Grant No.: BG-ARS-123
The online version is available at http:// www.springerlink.com

Sohag Miah • Soma Dey • S. M. Sirajul Haque (✉)
Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh.
Email: sohagm200431@yahoo.com

Responsible editor: Zhu Hong

this cultivation system was practiced only by 11 tribal communities with small number of people. Then they had the scope to shift from one place to other for cultivation of the land and they came back on the same land when land regained fertility after about 20 to 30 years. Thus, this shifting cultivation system was then environmentally suitable. It was found that the number of families of shifting cultivators over time increased rapidly from 2163 in 1964 to 35 000 in 2002 in CHTs (Tripura and Harun 2003). In this region, about 200-km^2 areas of various categories of forest lands are now being cultivated every year in this system (Tripura and Harun 2003). Shifting cultivation has now become unsustainable due to low production of crops because of reduction in land fertility through erosion for shortening of cultivation cycle to 2–3 years. Thus, at present, the produced crops from shifting cultivation can hardly sustain to the cultivators for about 3-4 months of the year.

There are several researches on soil and nutrient losses due to shifting cultivation in three neighboring small watersheds in CHTs (Gafur et al. 2000, 2003; Borggaard et al. 2003). No studies have been done so far on the effect of shifting cultivation on any microbial population, although they have immense ecological significance in the long run from environmental consideration. Under the adverse environment mentioned above, the present study was undertaken at two hill districts: Rangamati and Banderban of CHTs, to determine the effects of shifting cultivation on fungal and bacterial population in soil environment with the hypothesis that their population would certainly be reduced due to this cultivation system. In this over populated country, government policy was to encourage people to grow more agricultural crops to meet the immediate need. Therefore, people repeatedly clear and burn the area with natural forest in many cases in this hilly region.

Fungi and bacteria, grouped as secondary consumer as well as ultimate decomposer, perform many different activities as a tiller of wild soils. Fungi are heterotrophic in nutrition and form symbiotic associations with roots of higher plants, called mycorrhizae. This symbiotic association occurs in most plant species and nearly in all soils of the world (Harley and Smith 1983). Mycorrhizae play important role in tree growth through uptake of nutrients such as P, Zn, Cu, Mg, Mn and Fe from greater soil volume (Brady 1995). This symbiotic association also increases tolerance to toxins, temperature extremes and adverse soil pH conditions (Jackson and Mason 1984). Mycorrhizae also protect root system from many pathogens, absorb and translocate water to plant host, as well as provide resistance to drought for plant host. This mutually beneficial association enables host plant to absorb nutrients in an organic form, which otherwise is unavailable to plants. This symbiotic association also provides means of nutrient transfer from plant to plant by hyphal strands (Killham 1994). The most important practical use of mycorrhizae is that pine fails to grow in tropical countries without addition of suitable mycorrhizae in soil medium. Among all soil micro-biota, fungi with large diameter and extensive filaments produce the highest biomass (Killham 1994). However, their number is much lower than that of other soil micro-biota, particularly the bacteria. Cellulose and other materials such as hemi-cellulose, pectin, starch, fats and lignin of litters resistant to bacterial attack, particularly in acid condition, are attacked by fungi and converted to humus materials.

The bacteria are very important in many biochemical processes in soil due to their highest number among all the microbes. The nitrification process is very low in forest soil in general. This process is performed by chemoautotrophic and heterotrophic bacteria further reduced in acid soil (Pritchett and Fisher 1987). These two groups of bacteria produce small amount of nitrate from ammonium, but their large number is very significant to influence nitrate production under acid condition. *Thiobacillus thiooxidans*, acid-loving aerobes, are the most prevalent in forest soil. Decomposition of animal, plant and microbial residues is carried out by the heterotrophic bacteria. The chemoautotrophic bacteria in soil are largely nitrifier and also take place as sulfur oxidizer to a lesser extent. The bacterium *Nitrosomonous* converts NH_4^+ to NO_2^- and *Nitrobacter* converts NO_2^- to NO_3^- in presence of O_2 to accomplish nitrification process. Oxidation of elemental sulfur and sulfide to sulfate can be accomplished by both heterotrophs and chemoautotrophs. Bacteria of the genus *Thiobacillus* are the principal autotrophic oxidizers in well-aerated soil. Under anaerobic condition, oxidation is brought by *Thiobacillus denitrificans*. In waterlogged soil, inorganic sulfur is reduced by *Desulfovibrio desulfuricans* to produce sulfides (Pritchett and Fisher 1987). In addition to decomposition, the heterotrophic bacteria also perform non-symbiotic and symbiotic N_2 fixation. In non-symbiotic nitrogen fixation, various aerobic bacteria are *Azomonas*, *Azotobacter*, *Beijerinckia*, *Azospirillum*, and anaerobic bacteria include *Clostridium* and *Desulfovibrio.* The most important symbiosis is between leguminous plants and bacteria of the genus *Rhizobium* found in the nodules on roots of the species of Leguminosae family. The rhizobia infected and interacted with around 13 thousands different legume species (Killham 1994). The cyanobacteria can fix nitrogen and carbon dioxide directly from the atmosphere, and can colonize bare rock surface and initiate soil formation. The cyanobacteria forming lichen association with fungi also can act as primary colonizer and initiator of soil formation.

Materials and methods

Site description

The study was conducted in shifting cultivated and village common forest lands of two hill districts, namely Rangamati on 13 March and Bandarban on 9 August, 2008. Village common forests is also known as “mouza” forest, and managed by indigenous people in CHTs with the aim to meet own requirements. Village common forest is the better representation of once rich natural vegetation in CHTs, because at present natural forest does not exist in many areas in this mountainous region due to various human activities. Soil samples were collected from two pair sites representing shifting cultivated land and nearest village common forest land.

Rangamati

Shifting cultivated land of the first pair of site was beside Manikchari-Khagrachari road at Duluchari Para under Kutukchari union of Naniarsori Upazila in Rangamati hill district at 22˚42.132′N latitude and 92˚05.381′E longitude on the north-east aspect on the upper part of a gentle hill slope. In shifting cultivated land, about 70% land was without any tall vegetation; almost 95% land area without litter and exposed to sun light with the presence of few thickets such as *Saccharum spontaneum* (kash), *Mimosa pudica* (lajjabati) and *Eupatorium odoratum* (assam lata). Last year shifting cultivated crops were *Curcuma longa* (turmeric) and *Oryza sativa* spp. (paddy), and existing crops consisted of *Lablab purpurens* (bean) and *Manihot esculenta* (kasava) as vegetables. *Musa paradisiaca* (banana), *Artocarpus heterophyllus* (jackfruit) and *Mangifera indica* (mango) seedlings and 2-3 year old *Tectona grandis* (teak) saplings are on the border of the land only. A patch of 7–8 year old *Albizia procera* (shil koroi) with a maximum height of 16 m was present on the south-east side of this shifting cultivated area. The compared village common forest was situated 3 km away from shifting cultivated land at Madhya Para near Ban Bihar at 22˚42.343′N latitude and 92°05.40′E longitude on north east aspect of sites. Vegetation on the hill was not uniform and consisted of *Dipterocurpus turbinatus* (garjan) and *Melocanna baccifera (*muli bamboo) with a few shrubs such as *Clerodendrum viscosum* (bhat), *Garcinia cowa* (kaw), etc. giving 100% canopy coverage as top storey. *Melocanna baccifera* gave 60% coverage as under storey.

Bandarban

The second pair site was situated at Ampu Para beside Chimbuk-Thanchi road on the eastern aspect under Ruma upazila of Banderban hill district. Here, shifting cultivated land was on moderate or steep hill slope with scattered vegetation, such as *Bambusa tulda* (mitinga bans), *Albizia richardiana* (raj koroi), *Anarzicus accuminata* (koshoi), *Ficus hispida* (dumur), *Gmelina arborea* (gamar), *Artocarpus lacucha* (borta), *Smilax zeylanica* (smilex), etc. The village common forest was at Ampu Para at 21˚58.738′N latitude and 92°17.995′E longitude. This village common forest was situated 12 km away from the shifting cultivated land. Over the entire village common forest area, species composition was variable in patches with the presence of both natural and artificially planted species. Naturally growing forest was comprised of *Artocarpus chaplasha* (chapalish), *Dillenia indica* (chalta), *A. accuminata*, *E. odoratum*, several varieties of *Syzygium* spp. (jam), *A. procera*, etc. Planted species were *T. grandis*, *G. arborea* and *Schima wallichii* (kanak). However, *S. wallichii* was the dominant species in both natural and planted forest areas.

Soil sampling and analyses

The composites of 5 soil samples were collected randomly from soil depth of 0–10 cm and 10–20 cm covering each of the land use types: shifting cultivated and village common forest lands. Each soil sample was put in labeled poly bag sterilized with 95% ethyl alcohol. In the laboratory, the sieved dry soil sample was used for determination of soil texture by Bouyoucos hydrometer method according to Huq and Alam (2005) and moist soil pH at 1:2 soil-water ratios by TOA pH meter. A portion of the collected soil was kept in incubator at 4˚C for determination of microbial population.

Soil texture determination

For determination of soil texture, 25g of air-dried sample was taken in a 600-mL tall beaker, added 30 mL of concentrated H_2O_2 and kept over night covering with a clock glass. Then 200-mL of distilled water and 5 mL of 10% calgon solution were added to the contents in beaker. The contents were then removed to a 1000-mL sedimentation cylinder with distilled water using wash bottle and volume made up to the mark. Another blank set was arranged to add all the materials without soil. Temperature of the soil suspension in cylinder and the blank set was taken. Then the content was thoroughly mixed repeatedly. Hydrometer reading was taken at 40s, 4 min and 2 h from the start of settling of soil particles. From the observed hydrometer readings, percentage of each sized soil particles was calculated using equation (1).

$$R_c = (R - R_L) + (t - 20) \times 0.3 \quad (1)$$

where, R indicates hydrometer reading at 40s, 4 min and 2h, R_c is corrected hydrometer reading, R_L represents blank reading, t soil suspension temperature in sedimentation cylinder and 0.3 correction factor for each unit temperature (°C) rising or falling from standard 20°C. From the corrected hydrometer reading, percentages of sand, silt and clay were calculated using equations (2) to (7).

$$S_i + C = \frac{R_c}{O_w} \times 100 \quad (2)$$

where, R_c is corrected hydrometer reading at 4 min. O_w indicates oven dry weight of soil in g. S_i represents silt in %, and C is the clay in %.

$$C = \frac{R_c}{O_w} \times 100 \quad (3)$$

where, R_c is corrected hydrometer reading at 2 h, O_w the oven dry weight of soil in g, C represents clay in %.

$$S_i = (S_i + C) - C \quad (4)$$

where, S_i is the silt in % and C the clay in %.

$$S = 100 - (S_i + C) \quad (5)$$

where, S represents sand in %, S_i is silt and C the clay in %.

$$S_C = \frac{R_c}{O_w} \times 100 \quad (6)$$

where, R_c is corrected hydrometer reading at 40 s, O_w indicates oven dry weight of soil in g, S_c represents coarse sand in %.

$$S_f = S - S_c \quad (7)$$

where, S_f represents fine sand in %, S the sand in %, S_c is coarse sand in %. The calculated percentages of sand (S), silt (S_i) and clay (C) were then plotted on a soil textural triangle to determine textural class (Huq and Alam 2005).

Determination of microbial population

Fungi: Potato dextrose agar (PDA) media were used for culturing fungi. After primary washing with water, all glass wares used in microbial culture were ringed with 95% ethyl alcohol and wrapped with brown paper. The sterile media of PDA in conical flask were also wrapped with brown paper after tight cotton plucking. All the materials in wrapped condition were then placed carefully in an autoclave and sterilized at 121ºC for 15 min to free from undesired microorganisms. Exactly 1 g of soil sieved through 2 mm mesh size was dispersed in 99 mL of sterile water in a conical flask to produce 10^{-2} dilution. From this dilution of 1-mL suspension was taken out using sterilized pipette and mixed thoroughly adding 99-mL sterile water in another conical flask to give 10^{-4} dilution. In this way, dilutions were made up to10^{-5}, and dilutions of 10^{-3}, 10^{-4} and 10^{-5} were used for isolation of fungi. Each of the conical flasks with different dilutions was then covered with a rubber stopper. Three replicates of each dilution were prepared for each soil sample from each of the soil depths. Laminar flow bench was first cleaned with absolute alcohol using cotton and allowed to pass ultra violate ray until fluorescent light lit on. All the sterilized glassware and PDA media in conical flask were then transferred to the running lamina flow bench to avoid any contamination. About 15 mL of sterilized PDA media from conical flask was poured evenly throughout the petri-dish. Thus 18 different replicated cultures were prepared from PDA media. Exactly 0.1-mL streptomycin sulfate (0.25 mg·mL^{-1}) solution was added and spread to petri-dish for inhibiting any bacterial growth and allowed to solidify.

For isolation, 1-mL soil suspension was pipette out from each of 10^{-2} and 10^{-4} dilutions to the test tubes. Then 9-mL sterile distilled water was added to each dilution to give 10^{-3} and 10^{-5} dilutions, respectively. From each of the test tubes, 1-mL soil suspension was then pipette out and spread over the solidified media in petri dishes. After 72 hours incubation, all petri dishes were examined. Petri dishes which had >300 or < 30 colonies on the plates were discarded (Clark 1965). Any plates with fungal colonies in diameter greater than 2 cm were also discarded. Total number of colonies on each of the acceptable plates were counted using colony counter. The results were expressed as Colony Forming Unit (cfu) according to Clark (1965).

A very minute portion from the cultured colony was then observed under compound microscope at 10× and 40× magnifications to determine the structure of vegetative cells of fungi and the morphological structure such as presence of rhizoids or branched conidiophores or any other features to identify individual genus of fungus. One way analysis was done for obtained data to determine significance level for means between two land uses using Statistical Package SPSS 12.

Bacteria: For culturing bacteria, nutrient agar (NA) media were used and dilutions made up to10^{-9}. Dilutions 10^{-7}, 10^{-8} and 10^{-9} were used for bacterial culture. All the procedures described for fungi above were applied for the culture of bacteria. However, following exceptions were for bacterial culture. Each of the dilutions in conical flasks was shaken vigorously for 10 minutes. Nystate solution (0.005 mg·mL^{-1}) was used as antifungal culture. After incubation of 24 h, all petri dishes were examined. The bacterial cells singly in chain or in cluster were observed to identify individual bacterium.

Results

Rangamati

At Madhya Para of Rangamati hill district in Chittagong Hill Tracts, soil textures of surface (0–10cm) and subsurface (10–20cm) both in shifting cultivated land and village common forest varied from sandy loam to sandy clay loam (Table 1). At both the soil depths (0–10 cm and 10–20cm), pH at different hill positions was lower and moisture content significantly ($p \leq 0.05$) lower in shifting cultivated land, compared to nearest village common forest (Table 2). Surface soil pH at 0–10 cm depth on hill top was 5.10 in shifting cultivated land, and 5.36 in village common forest. For the same soil depth, moisture content in shifting cultivated land was 11.47% and in village common forest 17% (Table 2).

Fungi: In Rangamati, fungal population in both the soil depths (0–10cm and 10–20cm) on lower hill slope was significantly ($p \leq 0.05$) lower in shifting cultivated land, compared to village common forest (Table 3). On hill top, fungal population in both the soil depths was also lower in shifting cultivated land, compared to village common forest.

Fungal population on hill bottom at 0-10-cm soil depth in shifting cultivated land was 92 cfu and in village common forest 180 cfu ($\times 10^3 g^{-1}$dry soil). Fungal population in shifting cultivated land, ranged from 92 to 139 cfu ($\times 10^3 g^{-1}$dry soil), while in village common forest from 147 to 180 cfu ($\times 10^3 g^{-1}$dry soil). In whole of the soil depth (0-20cm), fungal population in shifting cultivated land was 108 cfu and in village common forest 160 cfu ($\times 10^3 g^{-1}$dry soil). Based on vegetative cell features of fungi, four different genera were identified in shifting cultivated land

and six genera in village common forest soil at this site. Among all, four genera: *Rhizopus*, *Aspergillus*, *Trichoderma* and *Penicillium*, were common both in shifting cultivated and village common forest land. Two other fungal genera, *Colletrotrichum* and *Fusarium*, were present only in village common forest soil.

Bacteria: Bacterial population at both soil depths on different hill positions in shifting cultivated land, except 10–20-cm depth on hill top, was significantly ($p \leq 0.05$) lower than that of village common forest (Table 3). Bacterial population on hill top at 0-10-cm soil depth in shifting cultivated land was 158 cfu and in village common forest 274 cfu ($\times 10^7 g^{-1}$dry soil). Population of this organism in shifting cultivated area ranged from 150 to 182 cfu ($\times 10^7 g^{-1}$dry soil), while in village common forest from 226 to 274 cfu ($\times 10^7 g^{-1}$dry soil). In whole of the soil depth (0-20 cm), bacterial population in shifting cultivated land was 168 cfu and in village common forest land 256 cfu ($\times 10^7 g^{-1}$dry soil). Three different forms of bacteria: *Streptococcus*, *Coccus* and *Bacillus*, were common both in shifting cultivated and village common forest soils.

Table 1. Soil textural characteristics from shifting cultivated land and village common forest at Madhya Para in Rangamati hill district

Land use	Hill position	Soil depth (cm)	Soil particles (%)					Textural class
			Coarse sand	Fine sand	Sand	Silt	Clay	
Shifting cultivated land	Hill top	0-10	25.60	48.80	74.40	4.00	21.60	[1]Sandy clay loam
		10-20	24.00	49.00	73.00	4.00	23.00	Sandy clay loam
	Lower hill slope	0-10	37.60	24.00	61.60	24.00	14.40	Sandy loam
		10-20	17.60	56.80	74.40	4.00	21.60	Sandy clay loam
Village common forest	Hill top	0-10	36.20	33.80	70.00	6.00	24.00	Sandy loam
		10-20	24.00	37.60	61.60	5.00	23.40	Sandy clay loam
	Lower hill slope	0-10	25.60	44.80	70.40	8.00	21.60	Sandy clay loam
		10-20	41.20	13.60	54.80	28.00	17.20	Sandy loam

Note: [1]Each texture is a composite of 5 soil samples collected from the field.

Table 2. Soil pH and moisture content in shifting cultivated land and village common forest at Madhya Para in Rangamati hill district

Hill position	Soil depth (cm)	Soil pH		Moisture content (%)	
		Shifting cultivated land	Village common forest	Shifting cultivated land	Village common forest
Hill top	0-10	[1]5.10	5.36	11.47*	17.00
	10-20	5.24	5.42	12.90*	15.41
Lower hill slope	0-10	5.16	5.53	13.75*	14.96
	10-20	5.20	5.46	15.88*	16.92

Notes: * represents significant difference at $p \leq 0.05$ for the means between land uses in each soil depth. [1]Each value is the mean of 3 sub-soil samples from a composite sample.

Table 3. Fungal and bacterial population in shifting cultivated land and village common forest soils at Madhya Para in Rangamati hill district

Hill position	Soil depth (cm)	Fungi cfu ($\times 10^3 g^{-1}$ dry soil)		Bacteria cfu ($\times 10^7 g^{-1}$ dry soil)	
		Shifting cultivated land	Village common forest	Shifting cultivated land	Village common forest
Hill top	0-10	[1]139	150	158*	274
	10-20	112	147	182	226
Lower hill slope	0-10	92*	180	180*	263
	10-20	87*	164	150*	260
Mean	0-20	108	160	168	256

Notes: * represents significant difference at $p \leq 0.05$ for the means between land uses in each soil depth. [1]Each value is the mean of 3 sub-soil samples from a composite sample.

Bandarban

Soil textures of surface and subsurface both in shifting cultivated and village common forest lands at Ampu Para of Bandarban district in Chittagong Hill Tracts varied from sandy loam to sandy clay loam (Table 4). At both the soil depths and different hill positions, pH and soil moisture content were lower in shifting cultivated land, compared to nearest village common forest with significant ($p \leq 0.05$) difference in few cases (Table 5). Surface soil pH at 0-10 cm depth on lower hill slope was 5.10 in shifting cultivated land and 5.40 in village common forest. For the same soil depth and hill position, soil moisture content in shifting cultivated land was 24% and in village common forest 24.54%.

Fungi: Fungal population in Bandarban was significantly

($p \leq 0.05$) lower in shifting cultivated area than that of nearest village common forest at both surface (0–10 cm) and subsurface (10–20 cm) soils on both top and lower hill positions except at 10–20-cm soil depth on lower hill slope (Table 6); however, here fungal population was also lower in shifting cultivated soil. Its population in the surface soil on hill top in the shifting cultivated area was 113 cfu and in village common forest 144 cfu ($\times 10^3 g^{-1}$dry soil). On an average, in the whole soil depth (0–20 cm), fungal population in shifting cultivated area was 116 cfu and in village common forest 144 cfu ($\times 10^3 g^{-1}$dry soil). Three genera of this flora viz. *Rhizopus*, *Trichoderma* and *Penicillium* were identified in shifting cultivated land and in addition, three other fungal genera viz. *Aspergillus, Colletrotrichum*, and *Fusarium* were found in village common forest soil at this site.

Bacteria: In Bandarban, bacterial population was lower in both the soil depths and hill positions in shifting cultivated area, compared to village common forest (Table 6). In the surface soil of hill top and in subsurface soil of the lower hill slope, the bacterial population was significantly lower ($p \leq 0.05$) in shifting cultivated area, compared to nearest village common forest. Their population in shifting cultivated land was 188 cfu and in village common forest 266 cfu ($\times 10^7 g^{-1}$dry soil) in the subsurface soil at lower hill slope. On an average, in the whole soil depth (0–20 cm), bacterial population in shifting cultivated area was 206 cfu and in village common forest 250 cfu ($\times 10^7 g^{-1}$dry soil). Three different genera of bacteria: *Coccus*, *Bacillus* and *Streptococcus*, were common both in shifting cultivated and village common forest soils.

Table 4. Soil textural characteristics from shifting cultivated land and village common forest at Ampu Para in Bandarban hill district

Land use	Hill position	Soil depth (cm)	Soil particles (%)					Textural class
			Coarse sand	Fine sand	Sand	Silt	Clay	
Shifting cultivated land	Hill top	0–10	36.00	28.00	64.00	16.00	20.00	[1]Sandy loam
		10–20	36.00	20.00	56.00	28.00	16.00	Sandy loam
	Lower hill slope	0–10	45.20	17.60	62.80	12.00	25.20	Sandy clay loam
		10–20	20.00	48.00	68.00	16.00	16.00	Sandy loam
Village common forest	Hill top	0–10	29.20	45.60	74.80	8.00	17.20	Sandy loam
		10–20	24.00	44.00	68.00	16.00	16.00	Sandy loam
	Lower hill slope	0–10	28.00	36.00	64.00	20.00	16.00	Sandy loam
		10–20	28.00	36.00	64.00	21.00	15.00	Sandy loam

Note: [1]Each texture is a composite of 5 soil samples collected from the field.

Table 5. Soil pH and moisture content in shifting cultivated land and village common forest at Ampu Para in Bandarban hill district

Hill position	Soil depth (cm)	Soil pH		Moisture content (%)	
		Shifting cultivated land	Village common forest	Shifting cultivated land	Village common forest
Hill top	0–10	[1]4.90	5.48	24.29*	25.59
	10–20	4.60*	5.50	20.13*	24.38
Lower hill slope	0–10	5.10	5.40	24.00	24.54
	10–20	5.15	5.35	24.57	22.79

Notes: * represents significant difference at $p \leq 0.05$ for the means between land uses in each soil depth. [1]Each value is the mean of 3 sub-soil samples from a composite sample

Table 6. Fungal and bacterial population in shifting cultivated land and village common forest at Ampu Para in Bandarban hill district

Hill position	Soil depth (cm)	Fungi cfu ($\times 10^3 g^{-1}$ dry soil)		Bacteria cfu ($\times 10^7 g^{-1}$ dry soil)	
		Shifting cultivated land	Village common forest	Shifting cultivated land	Village common forest
Hill top	0–10	[1]113*	144	215*	264
	10–20	98*	130	193	219
Lower hill slope	0–10	115*	158	226	249
	10–20	139	143	188*	266
Mean	0–20	116	144	206	250

Notes: * represents significant difference at $p \leq 0.05$ for the means between land uses in each soil depth.[1]Each value is the mean of 3 sub-soil samples from a composite sample.

Identification

Fungi: Colony characteristics of fungi from ocular observation provided preliminary idea about the types of organism and the vegetative cell features observed under microscope for identification of the genus. Six genera of fungi were found in soils of

Rangamati and Bandarban. Thus, characteristics such as irregular edge, round shaped and net-veined colony, whitish black color, presence of spores and scattered or periphery colony distribution indicated that it was a fungi colony. Presence of rhizoids and stolon with a group of sporangiophores was important feature to identify the genus *Rhizopus* (Rajan 2000). The other vegetative cell features that helped to identify this genus were columella with globular sporangium at the apex of sporangiophore. Moreover, sporangium contained large number of spores. Similarly, colony characteristics and vegetative cell features, such as swelling of conidiophores-tip forming a vesicle and containing number of sterigmata with conidia chain, indicated that the genus was *Aspergillus*. Some other distinctive colony characteristics along with vegetative cell features mentioned hereafter indicated that the genus was *Penicillium*. The distinguishing vegetative features for this genus included the branched conidiophore with several metulae at the end with 3-5 sterigmata growing from each metula with chain of conidia. The whole vegetative features of *Penicillium* together formed a brush like structure. The fourth identified genus was *Trichoderma* determined from distinctive colony characteristics and vegetative cell features. Vegetative cell features that confirmed this genus were the growth of more branched conidiophores and sterigmata either in single or in group with single celled conidia in cluster. The fifth identified genus was *Colletrotrichum*, determined from distinctive colony characteristics and vegetative cell features. One of the most important vegetative features for this genus was the presence of setae between conidiophores growing from acervulus and the other feature forming of unicellular conidia faceate with round ends. The genus with colony characteristics, such as regular edge and round shaped colony, milky white color, glossy appearance and scattered distribution, and vegetative cell features such as formation of septate sickle or crescent shaped macro-conidia, was confirmed as *Fusarium*.

Bacteria: Based on colony characteristics and vegetative cell features, three bacteria were found both in Rangamati and Bandarban. The colony characteristics, such as, irregular edge, deformed shaped, off white color, plain appearance and center or scattered colony distribution, indicated that it was a bacterial colony. The bacteria with vegetative features, such as rod shaped and elongated bacterial cell, were identified as *Bacillus* (Rajan 2000). The bacteria with vegetative features such as single isolated spherical cell were identified as *Micrococcus*. The bacteria with vegetative features were identified as *Streptococcus* (Rajan 2000).

Discussion

It is difficult practically in the field to find out undisturbed natural forest or any other natural vegetation adjacent to shifting cultivated land both at Rangamati and Bandarban districts. This was due to the repeated shifting cultivation on the same land and clearing forests over the past time, for which almost no land left as undisturbed natural forest. For this reason, village common forest was selected first in each locality. According to the site features of village common forest, such as topography, aspect, geology and soil through reconnaissance survey, the shifting cultivated land was selected on a site that had almost similar features. Thus, shifting cultivated site was situated slightly away from village common forest in both the locations. However, soil textures as well as particle distribution were similar on both the pair sites. Sandy loam to sandy clay loam soils were present both in shifting cultivated land and village common forest of Rangamati and Banderban (Table 1 and 4). Therefore, it was justified to compare for chemical and biological soil properties between the two different land uses in the present study. Both bacteria and fungal populations were lower in shifting cultivated soil, compared to village common forest soil at both Rangamati and Banderban districts (Table 3 and 6). One of the reasons was due to slash and burn during land preparation in this cultivation system. The other reason was the ecological difference between the two land covers. Shifting cultivated land at Rangamati possessed sparse vegetation having almost no litter and was exposed to full sunlight. The adjacent village common forest consisted of large sized tree species along with bamboo species giving full canopy coverage. Similarly, shifting cultivated land at Bandarban possessed the scattered vegetation of few trees with shrubs and was exposed to full sunlight. On the other hand, the village common forest was fully covered with canopies of large sized trees, both of natural and artificially planted species. This finding supported the hypothesis that shifting cultivation would reduce the population of fungi and bacteria. Several authors reported that pattern of response in total micro flora was associated with an immediate decrease in amount of microbes after burning of land (Bissett and Parkinson 1980; Beschta et al. 2004; Ahlgren and Ahlgren 1965), which supported present finding that fungal and bacterial population in shifting cultivated soil was lower than that in village common forest soil in both the localities. Moreover, soil moisture content was lower in shifting cultivated soil, compared to that in village common forest collected during dry season i.e. in March and August. Pritchett and Fisher (1987) also reported that microbial population was sensitive to fluctuation of soil moisture contents, which influenced microbial population. Dthar and Mishra (1987) found a positive correlation between bacterial population and soil moisture content in shifting cultivated land. Soil pH at both the locations showed that higher values had the tendency to increase the abundance of both fungi and bacteria. This finding was in agreement with the results of Anderson and Domsch (1993), who stated that low soil pH created stress condition on microbial community. In other words, less acidic soil is more favorable for most of the microbial community. Several reports also support present findings that forest vegetation becomes favorable to microbial communities. Gupta et al. (1986) stated that grass and forest lands had higher microbial population than shifting cultivated land. In the present study, fungi and bacterial population between the shifting cultivated land and village common forest was in agreement with the results of Dthar and Mishra (1987). They also found significantly lower microbial population in shifting cultivated land, compared to a land which had vegetation cover. Clearing and burning are the first two operations to prepare land in shifting cultivation system. Through

these activities, naturally growing woody and non woody vegetation completely destroyed, and in effect, many different ecological imbalances arise in the overall environment. Therefore, nationally and internationally alternatives of the shifting cultivation as a method to improve livelihood of million of people living in this hill districts with the aim to restore natural ecosystem need to be emphasized.

Shifting cultivation is not beneficial for soil environment in any way. This cultivation system reduces soil moisture content and populations of fungi and bacteria as well as their varieties drastically in soil. In this study, abundance and varieties of only two life forms have been explored. Further study is needed in this tropical region to understand further impacts of shifting cultivation on the myriad of organisms, which play many important beneficial roles in the soil environment.

Acknowledgement

The authors are grateful to Dr. Mostafa Kamal Pasha, Professor, Department of Botany, Chittagong University, for his help in identification of plant species during field work, and to Dr. Md. Nurul Anwar, Professor, Department of Microbiology, Chittagong University for his help in confirming soil microorganisms during laboratory work.

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